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Environmental Policy and the Green Transition: Impact on Global Trade and Supply Chains

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Abstract

The study aimed to identify the main changes in international trade in the context of achieving carbon neutrality. The research methods included analysis of the legal framework, analysis of official sources of documents, and secondary analysis of relevant reports. The study findings demonstrated that the green transition is shaping changes in supply chains and global trade. Therefore, the commitments under the Paris Agreement formed a regulatory framework within the European Union that promotes the sustainable supply of critical materials for the green transition. In the European Union, the green transition is being implemented under the European Green Deal to achieve carbon neutrality by 2050. Various mechanisms were created for this purpose, including the Emission Trading System, which can help achieve this goal but creates risks of economic polarisation within the European Union. Export restrictions on critical raw materials, which reached 30% in 2022, also pose a significant obstacle to the green transition. The problem of resource allocation was also evident in times of geopolitical tension. This is determined by the fact that most rare earth resources are in the bowels of the People's Republic of China and the countries that cooperate most closely with the Chinese government. At the same time, the resources of the United States and European countries are limited. This created opportunities for the formation of new trade relations. For instance, representatives of the European Union are actively cooperating with Africa to achieve both domestic carbon neutrality goals and the sustainable development of the African continent. As a result, international trade may change dramatically in the context of intensified trade between green governments, but this may only be possible in the long term.

Keywords

Critical resources; Investment; Renewable energy; Energy security; Trade restrictions

Introduction

In a rapidly changing world facing climate challenges, natural resource depletion and environmental crises, the green transformation of economies has become a critical priority not only for governments and corporations in the European Union and the United States but also increasingly for Asian countries and emerging economies across Africa and Latin America. Green transition policies centred on reducing greenhouse gas emissions and developing renewable energy affect both domestic economies and global trade patterns. Simultaneously, the uneven capacity of underdeveloped and developing countries to implement these transformations may exacerbate global economic disparities. Increasing demand for clean technologies, in particular hydrogen, and the need for innovation for decarbonisation are encouraging businesses and governments to rethink risk management strategies (Sinoimeri *et al*., 2024). This presents new opportunities for businesses that invest in the transparency and sustainability of their products and supply chains, contributing to meeting climate commitments and adapting to current trends (Lazaj, Teta and Xhafka, 2024).

As such, the study of the economic impact of green transformation in the 21st century is not only relevant but also necessary to determine the complex system of interrelationships within the framework of environmental priorities, technological progress and economic sustainability. Cui *et al.* (2022) discussed the green transition in the context of developed countries. In particular, the empirical results of their study demonstrated that international trade contributes to the green transformation in developed countries. In addition, the main driving force for the economic and environmental process is technological progress. Naqvi *et al.* (2023) studied the characteristics of economies in the G7 countries. The authors concluded that the transition to green energy and green industry has a positive impact on environmental quality, while the transition to green trade, on the contrary, does not help improve it. At the same time, financial development can help combat harmful emissions (Gritsuk *et al*., 2017). Murshed *et al.* (2022) considered aspects of achieving carbon neutrality in Argentina by 2050. The authors compiled a recommendation for the Argentine government, namely to take the necessary measures to switch to renewable energy sources in such sectors as electricity and to green trade globalisation strategies. Analyst Orhan (2022) studied the impact of the Russian-Ukrainian war on global trade. The results of the research demonstrated that policymakers need to ensure energy security and create conditions and opportunities for a green transition to minimise dependence on Russian energy resources.

Abasov (2024) described the opportunities and prospects for Azerbaijan during the period of declaring 2024 as the "Year of Green World Solidarity". In particular, the actions during this period were useful in terms of contributing to green public procurement in Azerbaijan, which aims to ensure environmental sustainability. The initiative increased demand for green goods and services for both local and international businesses and has strengthened the country's contribution to global efforts to combat climate change. Yüce (2023) also noted that the Zangezour Corridor is extremely important for the economic development of the region. In this context, US officials noted that American companies are seeking to participate in Azerbaijan's green energy projects. Shirizadeh *et al.* (2023) highlighted that global trade is crucial for the

development of cost competitiveness and sustainability of the clean hydrogen market. At the same time, the world's main trade routes are resilient to delays in hydrogen demand growth, which creates confidence in the effectiveness of future investments.

Given the above, the study aimed to identify changes in the global economy in the context of the zero-carbon approach. The objectives of the study were to identify changes in supply chains and analyse the competitiveness of green technologies.

Methodology

The study used documentary analysis to assess the legal and regulatory framework that defines the international and regional green transformation framework. This method structured information from official documents, such as agreements, resolutions and regulations that form the basis for economic policy making (Table 1).

Table 1: Data sources for analysing the legal and regulatory framework for green transformation

Source	*Type of information*	*Research method*	*Use in the study*
Paris Agreement (2015), United Nations Framework Convention on Climate Change (1992)	Legal and regulatory framework	Documentary analysis	Definition of global commitments to achieve carbon neutrality.
Greenly (Anderson, 2024)	Sustainability management tools	Software analysis	Exploration of opportunities to automate sustainability
World Trade Organisation (2001)	Zero tariff policy	Content analysis	Analysis of the peculiarities of introducing zero tariffs for green trade.
United Nations (UN-DESA, UNEP and UNCTAD, 2012)	Expert report	Secondary analysis	Assessment of economic preferences under green trade
International Renewable Energy Agency (2024)	Energy initiatives	Content analysis	A study of revenues for energy transformation.
Deutsche Welle (Kaufmann, 2024), LiveScience (Pare, 2024)	News articles	Content analysis	Analysis of the dependence of economies on critical resources

Source	*Type of information*	*Research method*	*Use in the study*
Resolution[1] of the Council of the European Communities and the Representatives of the Governments of the Member States meeting within the Council "On the Continuation and Implementation of a European Community Policy and Action Programme on the Environment" (1977), Regulation of the European Parliament and of the Council No. 2021/1119[2] "Establishing the Framework for Achieving Climate Neutrality and Amending Regulations (EC) No. 401/2009 and (EU) 2018/1999 ("European Climate Law")" (2021), International Energy Agency (2023)	EU legal and regulatory framework	Documentary analysis	Study of EU approaches to critical resource management
U.S. Mission Korea (2022), China's restrictions (De Santis, 2024)	US and Chinese policies	Content analysis	Analysis of trade relations between the US and China in the context of the green economy
EU and Chile (European commission, 2023b; European Commission, 2024b), EU and Kenya (European Commission, 2023a), EU and Africa (European Commission, 2024a)	EU cooperation with the regions	Analysis of documents and reports	Exploration of partnerships in critical resources for green transformation
European Green Deal (2024)	European initiatives	Documentary analysis	Assessment of the regulatory

[1] Resolution of the Council of the European Communities and of the Representatives of the Governments of the Member States meeting within the Council "On the Continuation and Implementation of a European Community Policy and Action Programme on the Environment". (1977). Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A41977X0613

[2] Regulation of the European Parliament and of the Council No. 2021/1119 "Establishing the Framework for Achieving Climate Neutrality and Amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ("European Climate Law")". (2021). Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1119

Source	*Type of information*	*Research method*	*Use in the study*
	under the Green Deal		framework for achieving carbon neutrality in the EU
Australia Department of Climate Change, Energy, the Environment and Water (Australia's international climate…, 2024)	Australian Government cooperation with partners	Report analysis	Study of the peculiarities of bilateral cooperation in achieving carbon neutrality
European Bank for Reconstruction and Development (2023)	Expert report	Report analysis	Dependence on critical resources for the energy transition
University of Zurich (Blanga-Gubbay and Khoban, 2024)	Scientific analysis	Analysis of policy and economic implications	The role of the Emission Trading System in the EU's energy transition
EU-US Trade and Technology Council (2024)	EU-US cooperation	Content analysis	Exploring aspects of trade coordination to achieve a green transition
Brookings (Arkolakis and Walsh, 2024), European Parliament (European Parliament , 2022), U.S. Department of Energy (2024), Directorate-General for Energy (2025), Techxplore (2024), International Energy Agency (2024)	Statistics and reports on the US, China, and the EU	Content analysis	Study of the economic and social benefits of the energy transition

Additionally, case study analysis was employed to illustrate and compare the impact of green transition policies on international trade and supply chains in specific national contexts. Selected cases, including the European Union, the United States, China, Australia, and African countries, were analysed to identify country-specific strategies, trade reconfigurations, and supply chain adaptations. This approach allowed for a deeper understanding of the practical implications and challenges associated with implementing environmental policies at both national and international levels. Content analysis was used to systematise data from publications, reports and news articles. This approach helped identify key trends and relationships between the green transition, economic preferences and international trade. This method provided an in-depth understanding of public and media assessments of the phenomena under study.

Results

International cooperation as a mechanism for shaping sustainability strategies during the green transition

The most important mechanisms that incentivise governments to green transition in 2024 are the Paris Agreement (2015) and the United Nations Framework Convention on Climate Change (1992). Their importance is determined by the exclusion of isolationism, a process that becomes counterproductive when it comes to global processes (Anderson, 2024). In particular, the Paris Agreement commits participating countries to increase their climate change commitments, known as Nationally Determined Contributions. A joint press release after COP29 indicated that the governments of the UK, Brazil and the United Arab Emirates are committed to keeping the climate to no more than 1.5ºC by 2035, while countries such as Bhutan, Madagascar, Panama and Suriname have already achieved zero emissions (Directorate-General for Climate Action, 2024). The Paris Agreement also mainstreams aid to developing countries through the Green Climate Fund. According to the Fund's open data library, as of early 2025, 286 projects in 133 developing countries (Pakistan, Azerbaijan, Angola, Mexico, Rwanda, Mozambique and others) have been approved with co-financing of 45 and total funding of 61 billion USD (Funded Activities, 2025). The Nationally Determined Contributions Partnership was also established to share knowledge on climate change. This organisation brings together more than 130 countries and more than 100 institutions to develop climate change actions to achieve the goals of the Paris Agreement.

Individual governments can achieve some progress and even positive results by acting alone, but such action will never be more productive than collective engagement. For instance, the "One Sun, One World, One Grid" initiative plans to connect 140 countries to a single solar energy grid, thus contributing to the goals of the Paris Agreement (International Solar Alliance, 2022). In addition, isolationist policies could ignore certain economic benefits of this kind of cooperation. In economies where green transition decisions are made, new markets and jobs are created (Kerimkulov, Teleuova and Tazhbenova, 2015). Co-operation, on the other hand, allows costs to be reduced and profits to be scaled. For instance, the Icelandic government's commitment to clean energy through geothermal sources has attracted investment from the most energy-intensive industries, like aluminium smelters, which have been attracted by competitive prices and reliability in electricity supply (Powers, 2022). In the context of supply chains, the close cooperation between EU member states and the adopted regulations (Regulation of the European Parliament and of the Council No. 2024/1252[3] "Establishing a Framework for Ensuring a Secure and Sustainable Supply of Critical Raw Materials and Amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020" (2024a), Regulation of the European Parliament and

[3] Regulation of the European Parliament and of the Council No. 2024/1252 "Establishing a Framework for Ensuring a Secure and Sustainable Supply of Critical Raw Materials and Amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020". (2024a). Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401252

the Council No. 2024/1735[4] "On Establishing a Framework of Measures for Strengthening Europe's Net-Zero Technology Manufacturing Ecosystem and Amending Regulation (EU) 2018/1724" (2024b)) will contribute to the sustainability of supply chains for zero-emission technologies (European Commission, 2024f).

The transition to a green economy has several important international dimensions (World Trade Organisation, 2001). Firstly, it is the very existence of international trade as an incentive for green growth, so trade capacity needs to be developed in a way that facilitates, rather than hinders, the green transition. Second, trade law is also necessary to shape the area of interaction between governments in pursuit of the green transition. One of the most effective examples of the use of global trade in greening the economy is the lowering of tariff barriers to trade in environmental engineering goods, whether wind turbines, solar panels, or energy-efficient light bulbs. For instance, the World Trade Organisation negotiations included the removal of trade barriers on environmental goods and services (UN-DESA, UNEP and UNCTAD, 2012). Through it, consumers, whether business or government, will be able to obtain environmentally friendly goods and technologies at low prices, and trade liberalisation will promote the use of environmental technologies, which will help increase innovation and technology transfer. According to the World Trade Organisation (2022) report, the largest number of trade tariff reductions were concluded between the EU and Vietnam, the Central American Common Market, Singapore, Georgia, Ukraine, and Japan, under the United States-Mexico-Canada Agreement. The elimination of trade tariffs can benefit the environment through the ability of developing countries to obtain high-quality environmental goods (World Trade Organisation, 2001). Trade liberalisation is also important in the context of helping developing countries address their underlying problems and key priorities in their development strategies. The main role of the World Trade Organisation is precisely to facilitate negotiations between governments. Direct financing is handled, for example, by the International Finance Corporation (2024). The organisation announced in early 2024 that it would finance USD 10 million in green bonds for a bank in Tajikistan to increase access to climate finance for small and medium-sized businesses. As a result, negotiating the removal of trade barriers to environmental goods and services creates buy-in from all parties, with trade and investment playing a crucial role.

The Intergovernmental International Renewable Energy Agency (2024) highlighted that most of the domestic investment in the green transition has been through financing from national sources, with little international cooperation. The International Renewable Energy Agency noted that international cooperation is key to stimulating financial flows to reduce inequalities. The limited public funds that exist in many developing countries require the mobilisation of funds from the Global North for the Global South, such as the mobilisation of funds from development banks (Niyazbekova *et al*., 2023). According to the International Energy Agency, EU and US investments in the green transition in 2024 amount to USD 450 billion and 500 billion. Among the Global South regions, the combined investments of India, Latin America, South Asia and Africa

[4] Regulation of the European Parliament and of the Council No. 2024/1735 "On Establishing a Framework of Measures for Strengthening Europe's Net-Zero Technology Manufacturing Ecosystem and Amending Regulation (EU) 2018/1724". (2024b). Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401735

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totalled USD 517 billion in 2024. The situation is dramatically different for investment in the PRC, which exceeded USD 800 billion in 2024 (International Energy Agency, 2024). Although international financial flows supporting the green transition have risen to over 15 billion USD – an increase of 25% compared to 2021 – according to the International Renewable Energy Agency (2024), these funds are concentrated in just a few regions, with 80% of the financial flows directed to only 25 countries (Figure 1).

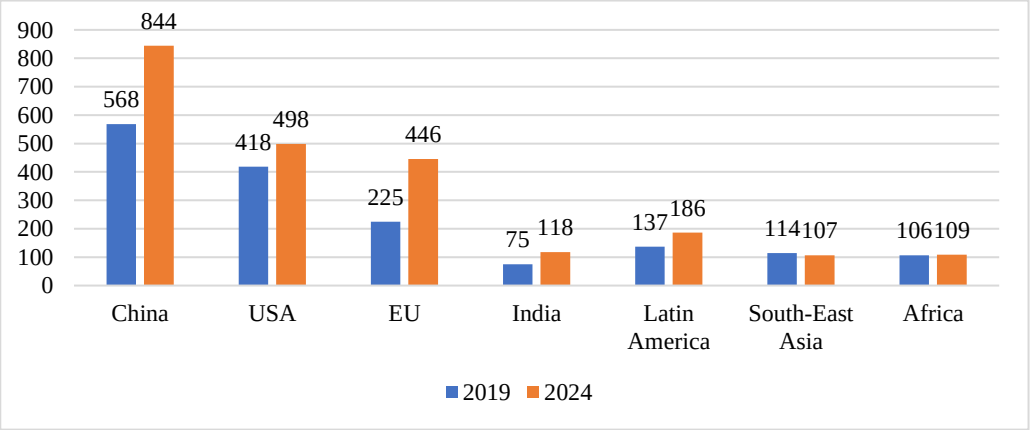

Figure 1: Investments in renewable energy by destination region (billion USD)
[*Source*: International Energy Agency (2024)]

As shown in figure 1, African countries receive minimal foreign investment and simultaneously face the highest costs for the green transition, even without accounting for their significant potential in renewable energy sources. In particular, the African continent is reported by the European Commission to possess 60% of the world's best solar resources (European Commission, 2024c). Accordingly, other regions, such as South Asia and Latin America, require greater attention from international donors and organisations to support the region's green transition. The research underscores investment disparities, emphasising that developing nations, especially Africa and Latin America, encounter significant obstacles in obtaining financing for their green transition. Despite international frameworks like the Paris Agreement pledging support for the Global South, the real allocation of funding is still constrained. International Renewable Energy Agency (2024) reports that merely 2% of global clean energy investment in 2024 was allocated to sub-Saharan Africa, despite the region holding over 60% of the world's optimal solar resources. In Latin America, despite significant renewable energy potential in hydropower, solar, and wind, funding obstacles remain due to political concerns, inadequate infrastructure, and an unfavourable investment climate (Allam, Bibri and Sharpe, 2022; Zakeri *et al.*, 2022). These structural impediments significantly constrain the scale of green technology and hinder its accessibility for local communities. A significant obstacle is the elevated cost of financing, which frequently exceeds the financial capacity of emerging nations. International Finance Corporation (2024) indicated that the capital cost for green projects in Africa is about twice that of developed economies, thereby diminishing the appeal of investments in sustainable energy.

Furthermore, the economic frameworks of numerous nations in Africa and Latin America continue to be significantly undiversified. Most function mostly as providers

of raw materials for green transitions in industrialised nations, failing to construct value-added sectors, hence constraining socio-economic advantages and exacerbating dependency (Salifu and Salifu, 2024). The absence of industry diversity impedes these regions' capacity to properly utilise the green transition as a driver of widespread economic growth. Overcoming these problems necessitates augmented financial resources, comprehensive structural reforms, improved institutional capacity, and the establishment of local value chains to facilitate a genuinely inclusive and sustainable green transformation. The International Renewable Energy Agency (2024) study also indicated that it is the G7 countries that cannot only be central but also potentially lead international cooperation to achieve the goal of 300 gigawatts of green energy by 2023. Therefore, mutually beneficial cooperation between the G7 countries and Africa offers a wide range of opportunities, including the expansion of infrastructure for access to finance, increased access to and productive use of energy, strengthened institutional frameworks, and, most importantly, effective management of critical raw materials for the green transition. The challenge, however, is that the availability of many critical raw materials important for the green transition in Africa is extracted merely to the exclusion of value-adding processes. That is, processes such as smelting, refining and others take place outside Africa. This would be the most beneficial model of cooperation for the African region, which would not only facilitate the green transition but also stimulate socio-economic growth.

An example of how a government directly benefits from intensifying international trade in the context of the green transition is Australia (Australian Government, 2024). The government is cooperating with international partners to promote practical action on climate change and create new clean energy industries. The range of goods and services supplied by the Australian government includes green hydrogen, solar PV systems, trading in hydrogen and its derivatives, ammonia, low-emission iron ore and steel, carbon storage, and emission reduction services for maritime and harbour operations, application of hydrogen in mining and heavy machinery operation, deployment of hydrogen hubs, development of certification schemes for hydrogen trade, development of government policies for hydrogen regulation. This cooperation aims to promote deeper cooperation to tackle climate change; support energy transformation at regional and global levels; diversify supply chains; and seek new trade opportunities for Australia. In total, partnerships in this format are being developed with the governments of the People's Republic of China, India, Germany, Japan, the Netherlands, the Republic of Korea, Singapore, the United Kingdom, and the United States.

The importance of hydrogen in the green transition has also been confirmed by petroleum geochemist Ellis (Pare, 2024). According to the author, the planet contains approximately 6.2 trillion tonnes of hydrogen, which is 26 times more than the known oil reserves, although it is not known exactly where these reserves are located and how cost-effective it will be to start searching for them. However, the important thing is that just 2% of the hydrogen reserves found in the study will be enough to provide all the hydrogen needed to achieve zero carbon emissions for several hundred years to come.

Features of the transition to green energy and changes in supply chains

The process of producing and transitioning to carbon-neutral energy is complex. It requires several critical resources, including copper for wiring, various rare earth metals for electric motors, lithium, graphite and nickel for batteries, and silicon for solar panels. By comparison, the production of a standard petrol-powered car, according to a report by the European Bank for Reconstruction and Development (2023), requires just over 20 kg of copper, 11 kg of manganese, and less than half a kilogram of zinc and other minerals. At the same time, the amount of materials needed to build an electric car exceeds 200kg. The list of these materials includes copper, lithium, nickel, manganese, cobalt, graphite, zinc and other critical materials. Extracting such quantities of raw materials for the green transition requires massive investments in mining and processing capacity. In the context of European governments and their green transition efforts, the 1977 Resolution[5] of the Council of the European Communities and of the Representatives of the Governments of the Member States, meeting within the Council, titled "On the Continuation and Implementation of a European Community Policy and Action Programme on the Environment", emphasized the European society's dependence on imported raw materials and the need for the rational use of available natural resources, which are either non-renewable or renewable only at a limited rate. Later, in 2008, the European Commission launched the Raw Materials Initiative, a strategic plan that developed mechanisms to address the problem of access to raw materials in the EU (International Energy Agency, 2023). The strategy was based on a fair and sustainable supply of raw materials in the EU and the supply of secondary raw materials through recycling. Similar initiatives were also adopted by other governments, notably the US, PRC and India.

However, given the growing demand for critical raw materials, the number of products that have been subject to export restrictions has also increased since 2020 (Montayev *et al*., 2023). According to Global Trade Alert (2025), the number of "harmful" interventions in nickel, copper, aluminium, lead, zinc and tin trade totalled 368 cases at the end of 2024, up from just 126 cases in 2020. Economies such as the PRC, the US and Vietnam witnessed the highest growth in critical materials subject to export restrictions. At the same time, several economies, such as Kyrgyzstan and Uzbekistan, have disrupted this process and reduced the share of critical materials subject to export restrictions. Export restrictions are imposed for one main purpose: either to extract value from a product by incorporating it into their domestic products or to make certain raw materials more expensive for end users (Jakubik, Kerimkhulle and Teleuova, 2017). One vivid example of export restrictions was the adoption of the Chips and Science Act in the U.S., which provided subsidies for the construction of semiconductor factories in the U.S., but such production could not be expanded in China or other countries that directly threaten U.S. national security (U.S. Mission Korea, 2022). The PRC authorities, in turn, in 2024 imposed export restrictions on gallium and germanium, some of the most critical materials for the development of advanced technologies (De Santis, 2024). There are several possible scenarios. First, the US government will need to diversify supply chains and invest in alternative mining locations. The same could help make impressive progress in reducing the PRC's influence on such situations in the future. In the most negative scenario, the relationship between the U.S. and China could turn into another economic and trade crisis. Such industries as telecommunications, renewable energy and

[5] Ibid, n.1

green energy may suffer. If the conflict escalates to an even greater scale and both governments impose new export restrictions and sanctions on companies, global markets could become even more polarised (Musayeva *et al*., 2024). This will have the greatest impact on small and medium-sized economies, which will have to choose which side to trade with in the face of ever-increasing prices for critical materials.

A study by the European Bank for Reconstruction and Development (2023) also highlighted that if a country does not have reserves of critical raw materials for the green transition, individual mining companies may seek to acquire mines or import materials from trading partners that are considered reliable. Reliability in this case means that the trading partner has similar values, interests and geopolitical intentions. To assess the similarity of values, the results of governments' votes at the United Nations General Assembly based on whether the country is more closely aligned with the United States (Block 1) or with the rest of the world, in particular China (Block 2), were compared (Figure 2).

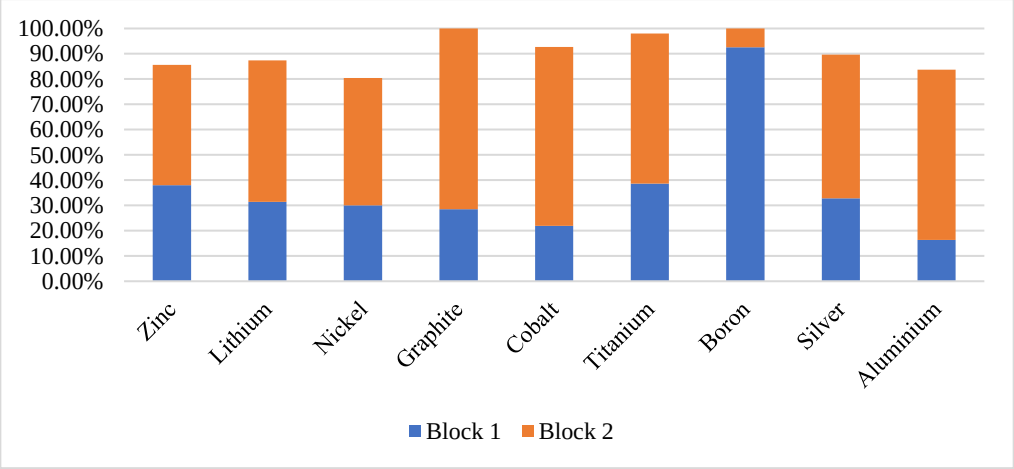

Figure 2: Global reserves of critical raw materials [*Source*: European Bank for Reconstruction and Development (2023)]

In sum, all known critical commodities are dominated by governments associated with the second block. However, first-bloc governments can establish and expand the production of some commodities given the escalation of geopolitical tensions (European Bank for Reconstruction and Development, 2023). For instance, the Czech Republic is one of the largest producers of electrical conductors, and Poland and Hungary export significant quantities of lithium-ion batteries, which together are important products for the green transition. The largest exporters of the first block's critical materials are the US, Japan and major EU economies. The greatest opportunities for expansion of production exist in Germany, Italy, Poland, Spain, and the Netherlands. European governments' attempts to reduce dependence on mineral imports from China are also related to this (Kaufmann, 2024). The economic impact of the green transition itself can vary from negligible to extremely high (Table 2).

Parliament (European Parliament, 2022), U.S. Department of Energy (2024), Directorate-General for Energy (2025), Techxplore (2024), International Energy Agency

(2024). The economic effects of the green transition differ markedly by location, mostly influenced by governmental goals and policy execution. The analysed cases illustrate that strategic planning can produce both economic and social advantages. The shift to a green economy necessitates significant expenditures in renewable energy and access to essential raw resources. In 2024, China and its associated nations will control the extraction, manufacturing, and processing of vital commodities necessary for the green transition. Nonetheless, alternative suppliers, especially Australia, are being incorporated into the developing global supply networks. Due to escalating geopolitical tensions and increasing rivalry for resources, a gradual yet substantial reorganisation of global supply and value chains is expected. Nonetheless, establishing alternative production capabilities, such as mining operations and processing facilities, is a protracted endeavour that could prolong geopolitical risks in the medium term.

Table 2: Economic benefits from the transition to green energy in different countries

Country	*Benefits from reduced CO_2 emissions*	*Number of new jobs*
USA	Reduced electricity prices by 20-80%, depending on the region	149.000 in 2023
EU	Under different scenarios, from -0.7% to 0.55% of GDP	More than 1 million by 2030
China	97% control of the solar panel market and higher cost competitiveness than in the US	2.5 million jobs in 2023

Source: Arkolakis and Walsh, 2024

However, numerous nations have commenced substantial endeavours to diversify supply chains. Australia is allocating more than AUD 2 billion to enhance its domestic lithium and rare earth processing capabilities by 2026 (Australian Government, 2024). Similarly, the Canadian Critical Minerals Strategy (2023) designates CAD 3.8 billion to ensure domestic production of cobalt, nickel, and rare earth elements, thereby diminishing dependence on imports from China. The EU's goal to diversify its key material supply chains has resulted in enhanced collaboration with Chile. The EU-Chile Advanced Framework Agreement (European Commission, 2023b) and the ensuing EU-Chile: Council Gives Final Endorsement to Bilateral Trade Agreement (European Commission, 2024b) seek to ensure access to vital resources such as copper, lithium, and green hydrogen. The accord grants mutual investment access for both Chilean and European participants. This accord signifies a constructive advancement in diminishing the EU's reliance on China; nonetheless, obstacles persist. The primary concerns are probable environmental repercussions linked to increased mining operations and the danger of perpetuating extractivist economic frameworks in resource-abundant nations such as Chile. Furthermore, competition for resources may intensify local socio-economic disparities, while environmental deterioration could present reputational threats to both Chile and the EU. Under the EU-Chile Advanced Framework Agreement (European Commission, 2023b), bilateral trade is projected to rise by almost 18% within the next five years. Exports of lithium from Chile to the EU are anticipated to exceed 100,000 metric tonnes per year by 2027, bolstering the EU's battery and electric car sectors (European Commission, 2023b).

Furthermore, the escalation of mining and resource extraction operations, propelled by the material requirements of the green transition, paradoxically threatens to compromise overarching climate objectives by augmenting emissions, habitat loss, and water use. Consequently, whereas accords such as the EU-Chile collaboration signify significant geopolitical diversification, they require strong sustainability frameworks to alleviate unexpected ecological and social repercussions.

Investments in green technologies as a factor of competitiveness in the global market

The European Green Deal (2024) embodies a highly ambitious global project aimed at attaining climate neutrality, targeting net-zero emissions by 2050. The enactment of the European Climate Law 2021 established interim targets: a 55% reduction in emissions by 2030 (compared to 1990 levels) and a 90% decrease by 2040 (Regulation of the..., 2021). The European Commission highlighted the necessity of achieving energy independence and bolstering resilience through the implementation of renewable energy, in light of the destabilising consequences of events like the Russian invasion of Ukraine (Shahini *et al*., 2023; 2024). Notwithstanding its extensive framework, the efficacy of the Green Deal encounters significant obstacles. The enhancement of the Emission Trading System (ETS) and the implementation of the Carbon Border Adjustment Mechanism (CBAM) are fundamental components. Empirical research (Blanga-Gubbay and Khoban, 2024) indicates that although the ETS facilitated a 35% decrease in emissions within covered sectors from 2005 to 2019, the progress did not meet initial objectives, largely attributable to low carbon prices (below €10) from 2013 to 2017 and the over-allocation of free allowances, particularly in energy-intensive sectors like steel (Gutarevych *et al*., 2020).

Despite recent measures intended to address these inefficiencies, additional dangers remain. The use of CBAM may incite trade disputes with foreign nations, particularly developing economies that view it as a protectionist strategy. Furthermore, although the Green Deal aims to transform European trade dynamics towards more sustainable industries and sectors (Kim *et al*., 2025), economic inequities within the EU may intensify. Highly industrialised Member States, such as Germany, France, and Spain, with more efficient green industries, are poised to gain disproportionately, while less advanced economies, including Hungary, Estonia, and Greece, may face economic marginalisation unless compensatory mechanisms, like the Just Transition Fund, are reinforced (Galkin *et al*., 2019). Moreover, the worldwide competitiveness of European enterprises may diminish due to elevated production costs linked to carbon pricing, potentially resulting in a loss of market share to competitors from regions lacking such legislative constraints. Furthermore, carbon-intensive businesses may migrate to regions with less stringent environmental restrictions, resulting in "carbon leakage" and compromising global climate mitigation initiatives (Borysiak *et al*., 2022a; 2022b).

In conclusion, the European Green Deal and the EU-Chile agreement are pivotal advancements towards a sustainable and resilient green economy; however, their efficacy depends on overcoming structural challenges, reconciling environmental sustainability with socio-economic equity, and alleviating geopolitical and market risks. A strong basis for cooperation on climate change and the green transition is the development of economic ties between the EU and Africa. The African continent is

among those that have contributed the least to climate change but have suffered the most. Climate change is causing more frequent droughts and thus intensifying desertification, which has a negative impact on agriculture and the agricultural sector (Kerimkhulle *et al*., 2021; Yerzhanova *et al*., 2021). A key aspect of cooperation that helps both sides to capitalise on the green transition is trade intensification. For instance, the Economic Partnership Agreement signed at the end of 2023 between representatives of the EU and the Kenyan government aims to stimulate trade in goods and increase investment for sustainable economic growth in Kenya (European commission, 2023a). According to the European Commission, the agreement is the most ambitious ever signed between the EU and a developing country when it comes to global challenges such as climate change and the environment. The agreement complies with the European Commission's agenda to intensify engagement with partners in Africa to achieve key objectives in the EU-Africa relationship and for a green transition, and recognises Kenya's development needs.

EU representatives are also actively cooperating with the US government on the intensification of green trade. For this purpose, the EU-US Trade and Technology Council (2024) was established back in June 2021 as a forum to discuss and coordinate approaches to key global trade, economic, technological and other issues. One of the priorities of the forum is to promote sustainable trade as an integral part of the green transition. To this end, the Joint EU-US Catalogue of Best Practices on Green Public Procurement (European Commission, 2024e) was created as one of the tools to accelerate the creation of public sustainability projects and improve cooperation on solar supply chains. Agreements were also reached between EU and US government representatives on the use of digital tools in trade (European Commission, 2024d). This will be achieved by introducing technical standards for electronic invoicing, which will not only eliminate bureaucratic costs but also significantly reduce the use of paper and therefore carbon emissions.

In summary, the impact of green transition policies on international trade and supply chains has demonstrated that green initiatives have significant potential to transform global trade, albeit with several challenges. Green technologies are changing the structure of the global economy, stimulating innovation, creating new jobs and reducing dependence on high-carbon energy sources. However, at the same time, there is a strong dependence on critical raw materials and rare earth metals, the extraction of which poses serious risks in the context of geopolitical tensions, requiring effective international cooperation. Policies aimed at reducing emissions are changing traditional supply chains, potentially shifting the flow of goods and services towards countries with high environmental standards. The introduction of systems such as the Emission Trading System creates a framework for the development of sustainable industries, but it may also cause a polarisation of the EU economy. This may particularly affect weak economies in the absence of adequate instruments to compensate for losses. In general, green policies, despite their many challenges, create new opportunities for the growth of trade in green goods and services. Implementation of such policies requires effective strategies for economic, social and environmental development.

Discussion

The transition to a green policy is a complex process in which supply chains and access to resources are important. In this context, even the creation of an electric car already poses serious challenges and costs compared to classic petrol vehicles. This indicates an increasing dependence on the extraction and processing of raw materials, which are key to the green transition. These findings correlate with the study by Herrington and Gordon (2024), noting the importance of effectively managing the risks associated with the extraction of critical feedstocks for the green transition. The authors also emphasised that proper regulation and optimisation of these processes are key to ensuring a sustainable zero-emission future. What is also important is the significant increase in demand for these resources, which is accompanied by rising geopolitical tensions. Based on the findings, around 30% of critical materials were subject to export restrictions in 2020-2024 due to localisation of government procurement and financial grants, a significant jump from 2020. This has contributed significantly to the rising cost of raw materials and incentivised changes in supply chains, as well as setting precedents for governments to try to mitigate risks by stopping the supply of certain groups of raw materials. Zhang *et al*. (2023) also highlighted that many global governments have decided to list rare earth metals as critical resources in 2023, confirming the critical importance of supply chain normalisation.

The green transition process is founded on structural modifications that have evolved over several decades. Since the 1990s, environmental policies have progressively emphasised the incorporation of sustainable development principles into economic and trade frameworks, initiated by the Earth Summit in Rio de Janeiro in 1992 and followed by the formation of the Kyoto Protocol in 1997. In the early 2000s, the focus on renewable energy sources, energy efficiency, and the trade of environmental goods became fundamental to international collaboration. The acknowledgement of vital raw commodities as strategic assets expanded post-2010, propelled by technical advancements in renewable energy, electric vehicles, and digitalisation. The European Union's Raw Materials Initiative of 2008 and the successive updates of crucial raw materials lists in 2011, 2014, and 2017 represented a substantial institutionalisation of resource security issues. The long-term developments established the groundwork for modern green transition policies, influencing regulatory frameworks and global supply chain plans. This study examines the recent dynamics of 2024–2025, recognising that these processes are rooted in long-term structural changes that have been progressively impacting international trade, energy security, and environmental governance for over thirty years.

However, international cooperation is fundamental to an effective green transition and a mechanism for creating the conditions for new markets (Trusova *et al*., 2021). However, geopolitical tensions and the economic crisis caused a significant decrease in financing for the green transition in Africa, Latin America and Eurasia (Kerimkulova *et al*., 2023). Cumulative investments in India, Latin America and South Asia in 2024 were the same as green transition investments in the EU. Zakeri *et al.* (2022) also highlighted that reduced international cooperation will hinder a sustainable energy transition. Allam, Bibri, and Sharpe (2022) also confirmed that countries in the Global South cannot adequately finance the green transition. Established supply chains are also important, as realised within the EU to achieve a green transition or high safety standards within the Australian government's hydrogen partnership. The importance of high safety standards in hydrogen supply chains was also noted by Noussan *et al.* (2020).

One of the mechanisms for accelerating the green transition in Africa, in addition to improving the region's trade opportunities, is cooperation with the G7 countries. The study demonstrated that an important aspect in this regard is the availability of rare earth metals in Africa, which are critical for the green transition of both Africa and the European region. However, the African continent itself has not sufficiently diversified its production to meet the challenges of the green transition. The low level of diversification of African industries in the context of the green transition was also highlighted by Salifu and Salifu (2024). An energy resource that can help the green transition is hydrogen, of which Australia is an example. The study determined that in addition to domestic needs, the Australian government is collaborating with many other governments to provide transport, strategy and management services to hydrogen hubs around the world. The critical role of hydrogen in Australia's trade was also described by Kar *et al.* (2023) as a strong hydrogen value chain in Australia's energy strategy.

One of the most important examples of creating conditions for a potential green transition of national economies analysed in the paper was the adoption of the Chips and Science Act in the United States (U.S. Mission Korea, 2022). However, the restrictions imposed therein have fuelled tensions with the PRC government, leading to a ban on exports of certain groups of metals in 2024. This could cause even more uncertainty, which could significantly alter global trade towards even greater polarisation towards the US side. Luo and Van Assche (2023), while recognising the above aspect, noted that US partners with similar priorities in semiconductors, whether Taiwan or the Republic of Korea, may end up being out-competed due to technological nationalism on the part of the US government. In the same context, the problem of the acute dependence of many economies, particularly the EU, on critical resources that are mostly sourced from the PRC or countries that closely cooperate with the PRC is also relevant (Qawaqzeh *et al*., 2020; Szafraniec *et al*., 2021). In this context, an agreement between the EU and Chile, as well as other governments' efforts to diversify economies and increase bilateral trade, could help achieve the green transition more effectively, albeit more difficult given the dependence on PRC resources. Nygaard (2023) also highlighted as a critical issue the resource dependence of the EU and the US on authoritarian, corrupt and unreliable trading partners, which increases the geopolitical risks for the green transition.

Moreover, the polarisation of international relations over resource control presents strategic problems. Over two-thirds of essential resources are situated in or processed by China and its allies (Månberger, 2023). Shahini *et al.* (2022) assert that Western economies must cultivate new extractive capabilities; nevertheless, this objective encounters environmental, economic, and social challenges. Cristea *et al.* (2023) advocate for a gradual shift towards low-carbon industries, whereas Vezzoni (2023) challenges the persistent impact of Chinese mining firms, observing that Western bloc nations such as Japan may progressively lead the market for crucial components (Jones, Nguyen-Tien and Elliott, 2022).

The European Green Deal (2024) is substantial in terms of the green transition in the EU. Commitment to green technologies and a shift away from high-carbon industries could be a factor in future changes in EU trade patterns, where trade with similar green countries will be favoured, as shown in the study. The above assertions are also present

in a study by Sandri *et al.* (2023). In addition, the authors specified a possible increase in the importance of countries such as Morocco, Jordan, Egypt and Tunisia in the EU trade structure. At the same time, carbon-dependent European industries and firms may not be able to cope with the new restrictions on carbon use, which would shift some production either outside the EU or from less developed to more developed countries within the EU, as evidenced by the University of Zurich (Blanga-Gubbay and Khoban, 2024). Clausing and Woflram (2023) similarly indicated that the high cost of energy inputs may favour the relocation of carbon-intensive industries to other countries. The same, which was also demonstrated in the study, could lead to the polarisation of economies within the EU, which would negatively affect multilateral trade between the EU and the rest of the world. The aspect of polarisation of intra-European economies was also highlighted by Chakraborty, D'Amato and Mazzanti (2023), pointing to the reality of changes in trade due to carbon taxation.

Trade agreements, such as those between the EU and African countries, are essential for intensifying green transition efforts. While Petrone (2023) notes a trade imbalance, the lack of capacity for value-added products in Africa remains a significant barrier. Enhanced EU-US trade relations, facilitated by the EU-US Trade and Technology Council and other mechanisms, could significantly boost green trade and reduce dependence on Chinese exports (Guinea *et al.*, 2024). In conclusion, the green transition is essential for attaining global sustainability objectives, although it concurrently presents new economic, political, and environmental concerns. Confronting these issues necessitates a thorough revaluation of existing methods, improved international collaboration, and a deliberate endeavour to reconcile environmental goals with socioeconomic conditions and geopolitical intricacies.

A comparative examination of the discussed case studies demonstrates substantial disparities in the impact of various governments' approaches to the green transition on international trade and supply chain restructuring. The European Union's policy, grounded in extensive legislative frameworks like the Green Deal and Emission Trading System, promotes the diversification of trade alliances, especially with resource-abundant areas such as Africa and Chile, to diminish reliance on essential raw materials. Conversely, China's supremacy in the extraction and processing of essential resources allows it to consolidate supply chain control, thereby shaping global trade patterns towards more centralised models. Australia's plan, centred on augmenting green hydrogen exports and establishing bilateral agreements, exemplifies an alternate type of supply chain internationalisation predicated on technology specialisation rather than raw material extraction. The United States' strategy, focused on technical independence programs like the Chips and Science Act, generates substantial trade disputes that intensify the polarisation of global supply networks. Diversification tactics establish new trade channels and supply networks, however concurrently heighten rivalry for resources and elevate transaction costs for smaller economies. African economies, despite their considerable resource potential, primarily function as providers of raw materials, without integrated value-added industrial chains, which restricts their capacity to impact global trade dynamics during the green transition.

Consequently, whereas the global green revolution promotes trade in environmentally friendly goods and services, it also asymmetrically reorganises supply chains, potentially

exacerbating structural imbalances among countries and regions. These disparities highlight the necessity for sustainable value chain development strategies that simultaneously address environmental objectives and foster inclusive economic involvement. Furthermore, the escalation of geopolitical threats generates ripple effects on resource supply stability, conflict emergence, and global supply chain disruptions. Resource scarcities, particularly concerning essential minerals like lithium, cobalt, and rare earth elements, are increasingly associated with geopolitical rivalry. The concentration of these resources in a few nations, particularly China and its strategic allies, renders supply chains vulnerable to political manipulation and trade weaponisation, potentially leading to severe shortages for industries reliant on clean technologies. In situations when political conflicts intensify – such as trade wars or territorial disputes – the accessibility of critical resources for renewable energy infrastructure, electric vehicles, and digital technologies may be significantly hindered. Historical precedents, such as export bans and retaliatory tariffs, highlight the vulnerability of these supply chains during geopolitical tensions. As a result, corporations and governments must revaluate their risk management policies, emphasising diversification, onshoring, and the creation of strategic reserves to alleviate potential shocks. Moreover, geopolitical fragmentation threatens to disrupt the global green transition, resulting in the formation of rival "green blocs" with differing standards, complicating global trade and cooperation frameworks.

Conclusions

The study highlighted that green transition policies affect global trade and supply chains, demonstrating the complexity of this process. The implementation of green policies is becoming a catalyst for the transformation of global markets, influencing their reorientation towards environmental development. However, the implementation of green policies can also have negative consequences for supply chains. This is reflected in the dependence on critical resources such as lithium or cobalt, and other rare earth metals, which creates challenges for global trade. In addition, the export of such materials faces an increasing number of different political obstacles, which have increased since 2020. In the same context, it is important to distribute these resources among geopolitically diverse governments, as a significant portion of the resources, on average 50 to 70% or more, are in China and countries that closely cooperate with China. Also, dependence on critical resources requires the development of strategies to reduce dependence, the development of recycling technologies and the search for new trade markets, which can only be helped by intensified international cooperation.

The study also revealed that intensified international cooperation positively affects the overcoming of barriers related to the green transition. The EU and US governments are seeking to promote multilateral trade to reduce resource dependence on the PRC, which effectively dominates the upstream and downstream markets for many critical resources. The EU-Chile agreement is a prime example of efforts to diversify trade ties and ensure access to the raw materials needed to achieve climate neutrality. Diversifying trading partners helps create new supply chains, which not only reduces risks but also improves global economic stability. Individual economies also benefit socially from the energy transition. This has resulted in 2.5 million jobs in the PRC, 149,000 new jobs in the US, and within the EU, it is projected that over 1 million jobs will be created by 2030.

The study also emphasised that one of the key aspects in shaping the global economy of the green transition period is the creation of sustainable supply chains. Such chains should be as efficient as possible and protected from geopolitical risks. Co-operation between the EU and Africa could potentially establish such chains, but the challenge remains the lack of value-adding capacity on the African continent. Additionally, the polarisation of economies remains a challenge. While the largest investments in the energy transition exist in Europe, the US and the PRC, with USD 446, USD 498 and USD 844 billion respectively, Africa and Latin America, as well as Southeast Asia, have a combined investment of only USD 402 billion in 2024. A successful green transition, however, requires long-term support programmes that equally address the social and economic challenges of the regions. Sustainable development on the African continent could significantly ease increasingly complex supply chains, while financing the region would reduce economic polarisation and protect global trade from geopolitical risks. Future research on the topic could cover the long-term effects of the Emission Trading System as well as the role of digitalisation in the green transition.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*
Conceived and designed the research or analysis	Yes	No
Collected the data	Yes	No
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
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